FIG. 6b. The converted and gridded version of the same data as used for 6a.

mosaic picture. As the pictures do overscan each other considerably, a simple method of calculating the speed of depressions and fronts is given. The results are quite acceptable in spite of the applied approximations.

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# A Technique for Obtaining Detailed Wind Fields in a Frontal System from a Single-Doppler Radar[1]

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## ABSTRACT

A technique is described for obtaining detailed horizontal winds in a "two-dimensional," steady-state frontal system from a single-Doppler radar. Measurements obtained from this technique in a cold frontal system are presented.

## 1. Introduction

As part of the University of Washington's CYCLES (CYCLONIC Extratropical Storms) PROJECT a number of new techniques are being explored for the use of single-Doppler radars in studying cyclonic storms. In previous publications we have described how measurements from a vertically pointing Doppler radar can be used to deduce the modes of growth of ice particles

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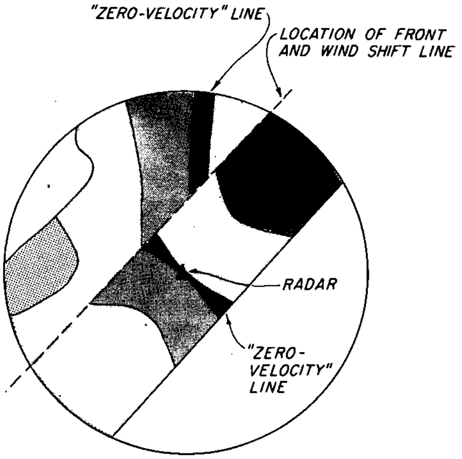

FIG. 1. Schematic of Doppler velocity pattern (at 0° elevation angle) in the vicinity of a front. The various shadings indicate different Doppler velocities.

(Weiss and Hobbs, 1975) and the types of ice particles (Weiss *et al.*, 1977). We have also described (Baynton *et al.*, 1977) how various wind fields associated with cyclonic storms can be detected in real time through simple pattern recognition using a color display, scanning Doppler radar. In this note we describe a technique which, under certain conditions, can be used to obtain very detailed wind measurements in frontal systems.

## 2. Description of the technique

The technique to be described is based on the well-known Velocity-Azimuth-Display (VAD) method for measuring horizontal winds in precipitation having uniform motion [see Battan (1973) for a review of this technique]. However, by making use of the essentially two-dimensional structure and quasi-steady-state nature of many fronts, we extend the VAD method so that it can provide more detailed wind fields in frontal systems than have been previously available.

Shown in Fig. 1 is an idealized representation of the Doppler velocity pattern in the vicinity of a front. The wind shift across the front results in a discontinuity in the Doppler velocities. (In the NCAR Doppler radar, which we have used, each velocity is displayed as a different color; therefore, any discontinuity across a wind shift line is particularly striking.)

The direction of the wind at any point on the "zero-velocity" line is normal to the radial connecting that point to the radar. Hence, the winds along the "zero-velocity" line in Fig. 1 are as shown in Fig. 2a. The velocities of the wind can be determined from the usual VAD method. Now, if the winds do not vary appreciably along the length of the front (but only normal to it), the derived winds along the line AB in Fig. 2a can be shifted down onto the line XY as shown in Fig. 2b.

If VAD's are obtained at different elevation angles, each series of scans (e.g., covering elevation angles 0–20° at 1° intervals) can be used to deduce the horizontal winds at different levels through a plane which is normal to the front. This is shown schematically in Fig. 3. However, because of the spacing between the elevation angles and the position of the front with respect to the radar, this still provides only a partial view of the horizontal wind field. A much more detailed view can be obtained by combining the wind measurements from many such series of scans which are acquired as the front passes through the area covered by the radar (Fig. 4). The measurements from the various series of scans can then be superimposed onto one plane after they are aligned by matching their wind shift lines. This provides a very high density of wind measurements for the whole frontal system.

It should be emphasized that this technique depends on two assumptions. First, that the horizontal winds do not vary appreciably parallel to the length of the front and, second, that the winds in the frontal system do not change appreciably during the period of the measurements. However, the period of time and the region in space for which these assumptions are valid can be readily determined from the radar observations.

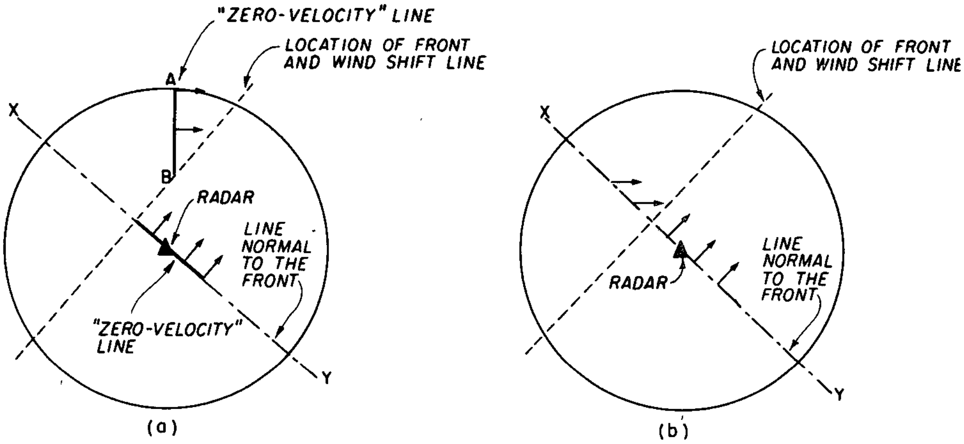

FIG. 2. Wind directions along (a) the "zero velocity" lines in Fig. 1, and (b) the line XY.

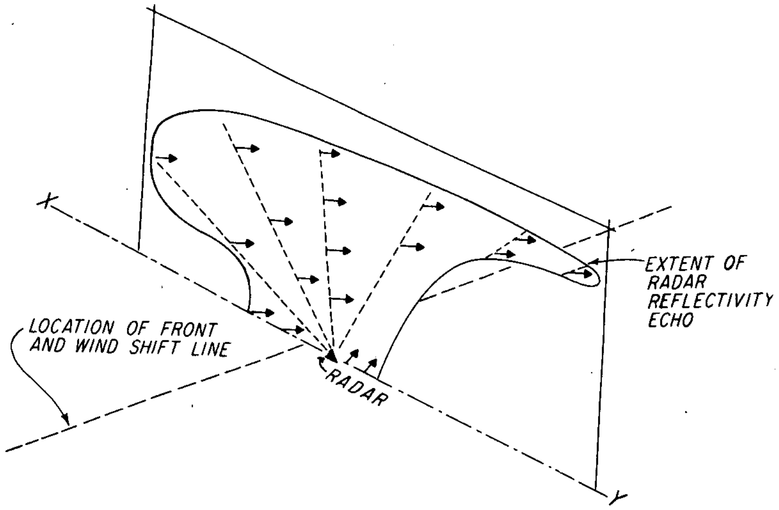

FIG. 3. Schematic of horizontal winds through a plane normal to the front derived from one series of VAD scans.

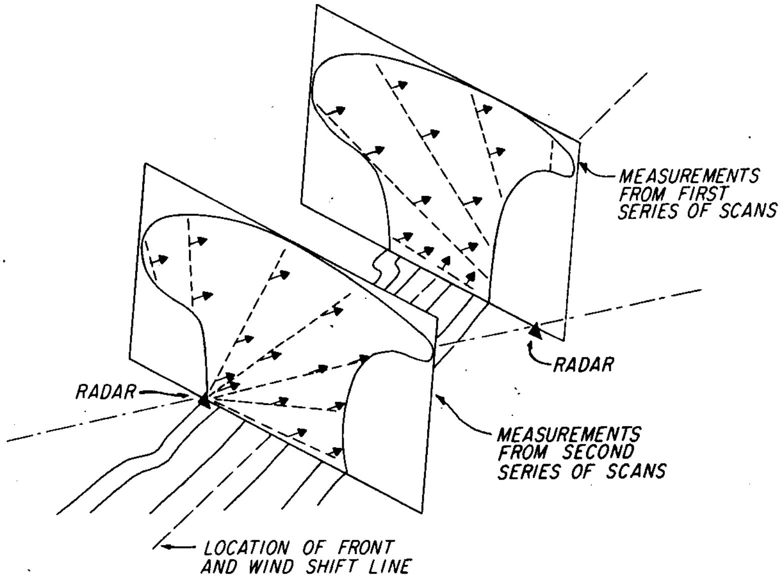

FIG. 4. Schematic of horizontal winds obtained from two series of VAD scans as a front moves across the radar.

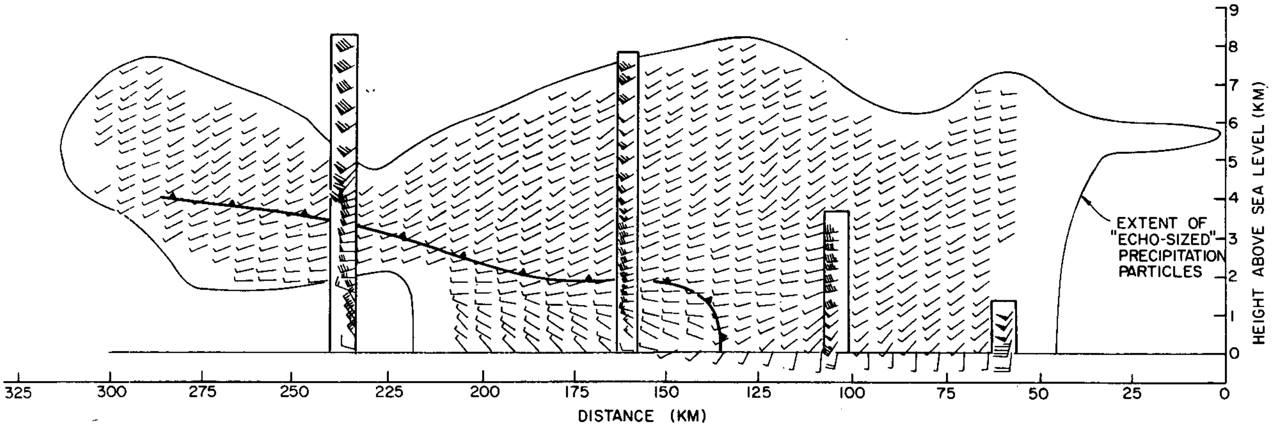

FIG. 5. Horizontal wind field (small arrows indicate directions only) derived from the radar technique described in this paper for a cold frontal system which passed over western Washington on 17 November 1976. Serial rawinsonde measurements (showing wind directions and speeds) are plotted within the rectangular boxes.

### 3. Illustration of the technique

Shown in Fig. 5 is the wind field, deduced by the technique described above, for a cold frontal system which passed over the western part of Washington State on 17 November 1976. The tremendous detail obtained from this technique is clearly apparent when compared to the coverage provided by the rawinsondes (shown within the rectangles in Fig. 5), even though the latter were launched about every 1½ h. It can be seen that the wind directions deduced from the radar measurements are in good agreement with the adjacent rawinsonde measurements. The wind shift across the front is revealed by the radar measurements, as is the cold air advection (winds backing with height) behind the front. Clearly, detailed information on small mesoscale regions can be obtained with this new technique.

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# Modified Cine Sound Camera for Photographing Thunderstorms and Recording Lightning

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### 1. Introduction

A cine super-8 sound camera, by the addition of a simple photocell optical system, can be used not only to photograph thunderstorms but simultaneously to record optical characteristics of lightning events occurring within them.

### 2. The camera system

Griffiths and Vonnegut (1975) have described a simple apparatus consisting of a photocell and a tape recorder for detecting and recording characteristics of lightning. With this system, light from the discharge, either scattered or direct, is converted by a photocell optical system into an electrical signal and recorded on a magnetic tape for later analysis. This arrangement can record lightning at night and also detect and record lightning in clouds illuminated by direct sunlight, even when it cannot be seen by the human eye. By using an appropriate lens with the photocell, the angle of acceptance of the system can be limited so that only flashes from a particular cloud or portion of a storm are recorded.

In studies of thunderstorm electricity it is of interest

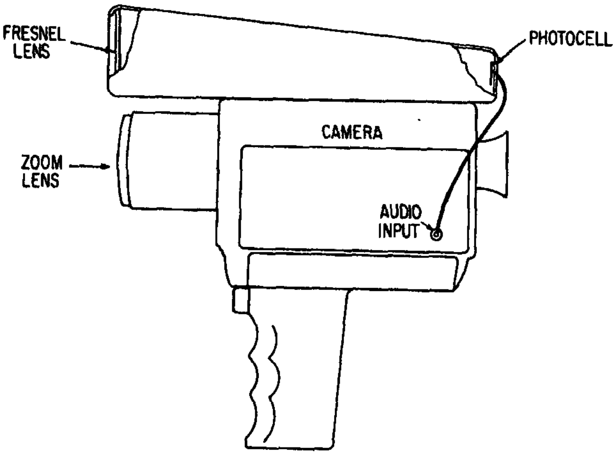

Fig. 1. Diagram of super-8 sound camera and optical system.

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